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(54) **SEMICONDUCTOR DEVICE, METHOD OF MANUFACTURING THE SAME, CIRCUIT SUBSTRATE AND ELECTRONIC EQUIPMENT**

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(57) **ABSTRACT**

A method of manufacturing a semiconductor device includes (a) connecting a first substrate with a second substrate disposed to be stacked on the first substrate and (b) cutting the first substrate and the second substrate in the same process with a cutting tool. The cutting tool includes a plurality of cutters disposed close to each other, having different cut widths and the first substrate and the second substrate are cut with the cutting tool so that the first substrate and the second substrate have different cut widths, in step (b).

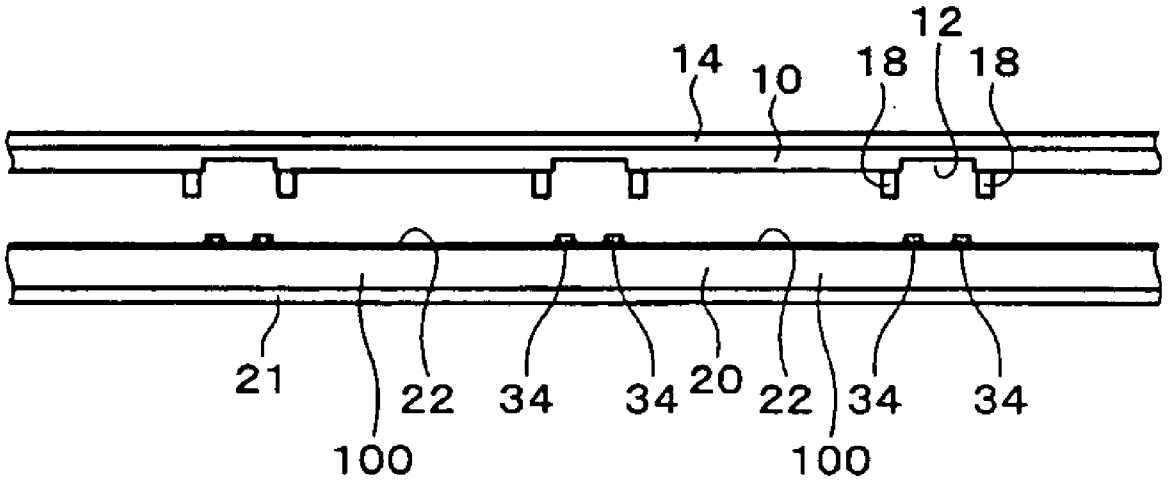


FIG.1 (A)

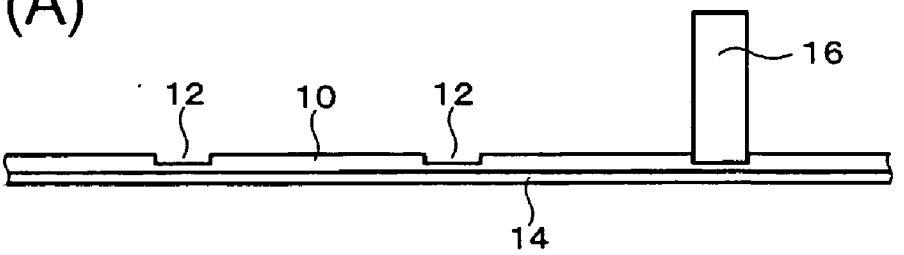


FIG.1 (B)

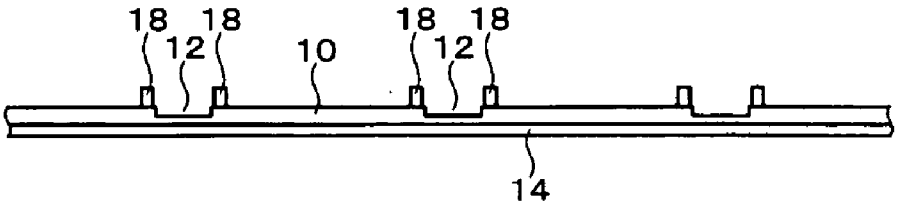


FIG.1 (C)

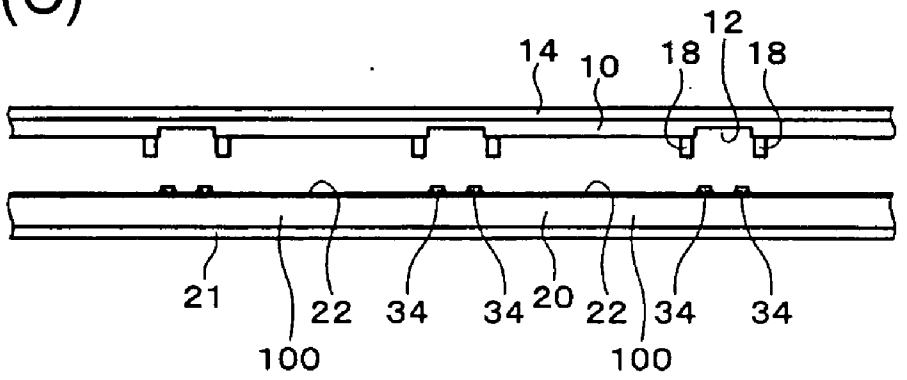


FIG.2

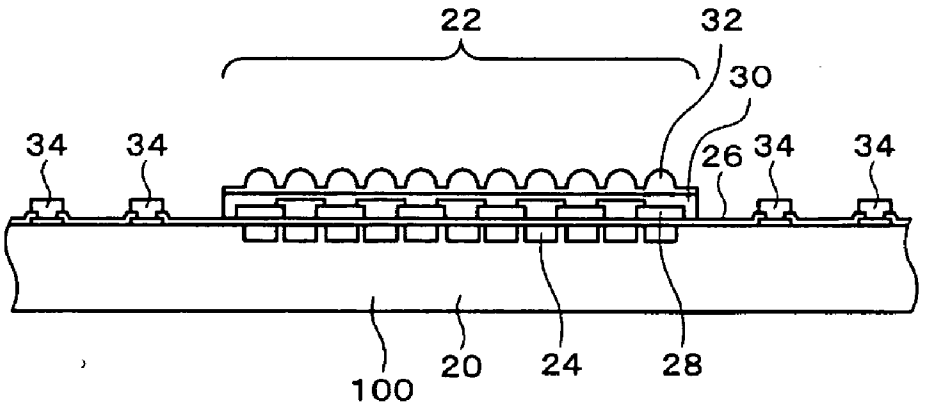


FIG.3

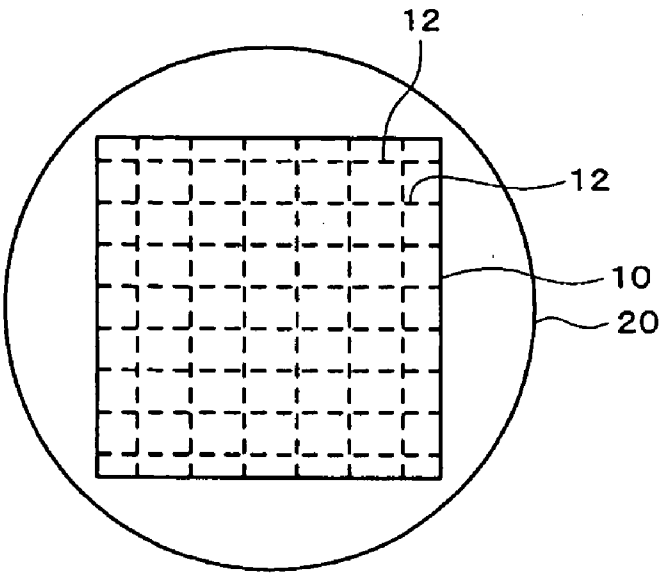


FIG.4 (A)

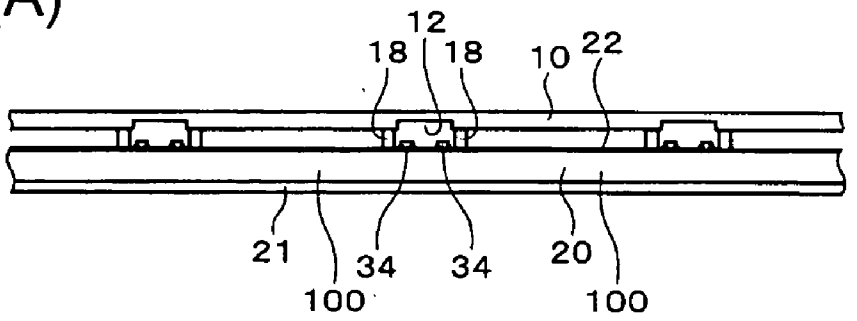


FIG.4 (B)

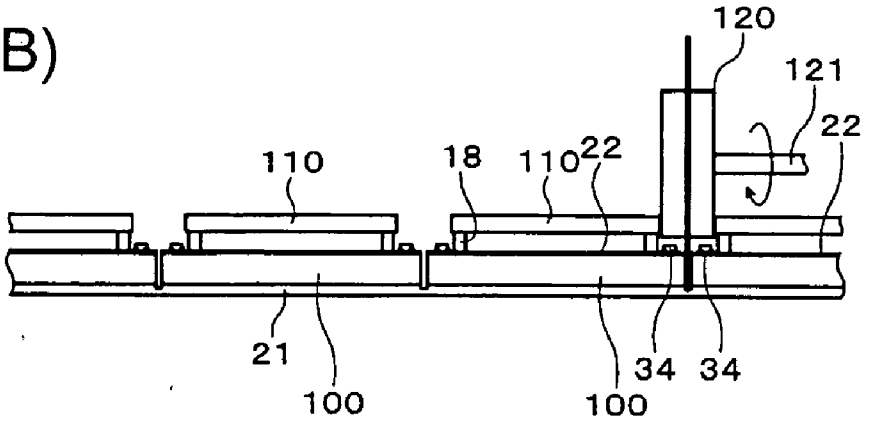


FIG.5 (A)

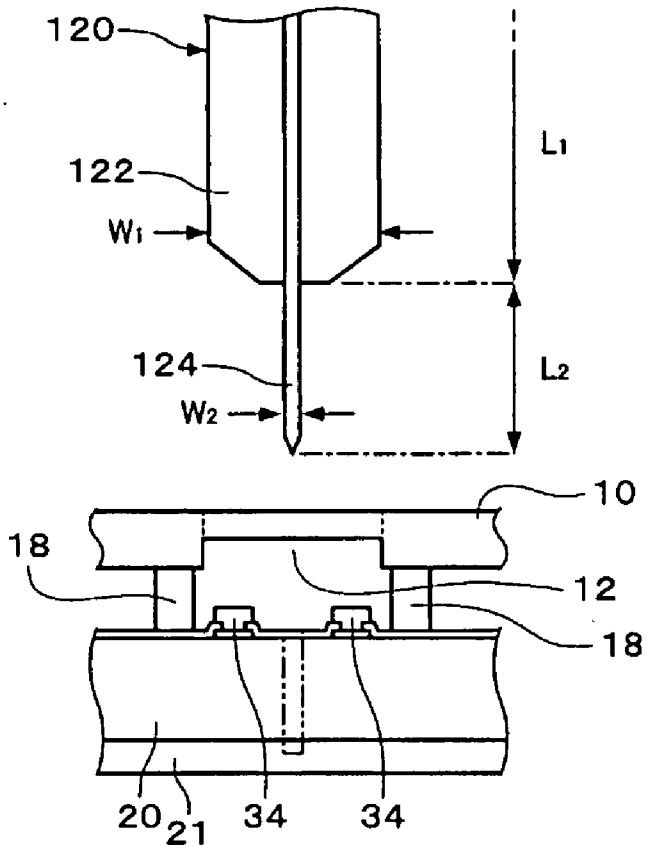

120
122
W1
L1
124
W2
L2
10
18
12
18
20
21
34
34

FIG.5 (B)

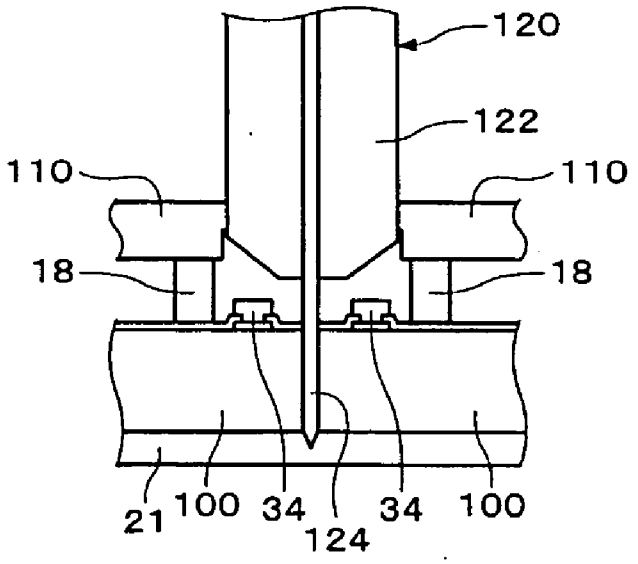

120
122
110
110
18
18
21
100
34
124
34
100

FIG.6 (A)

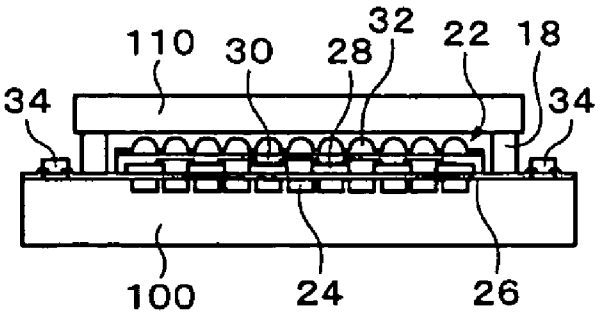


FIG.6 (B)

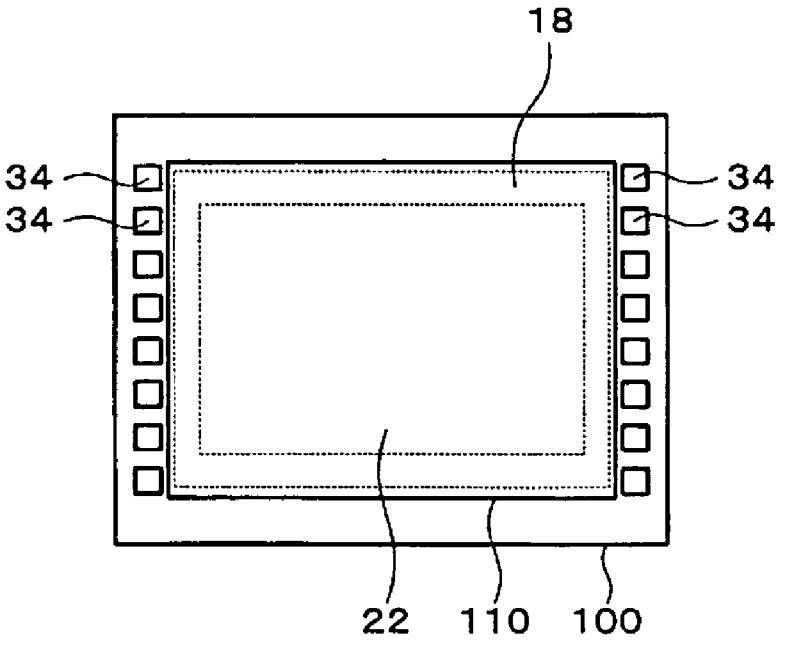


FIG.7 (A)

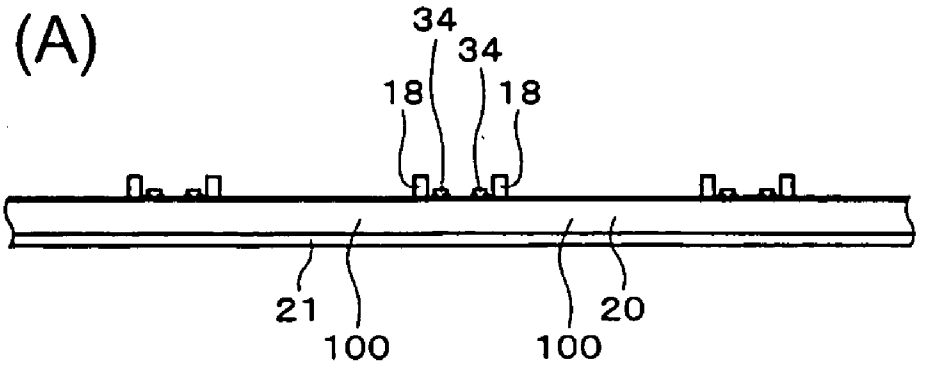


FIG.7 (B)

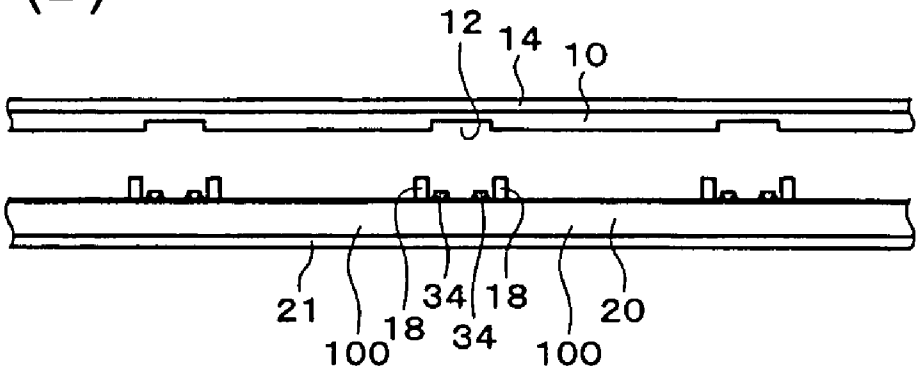


FIG.8 (A)

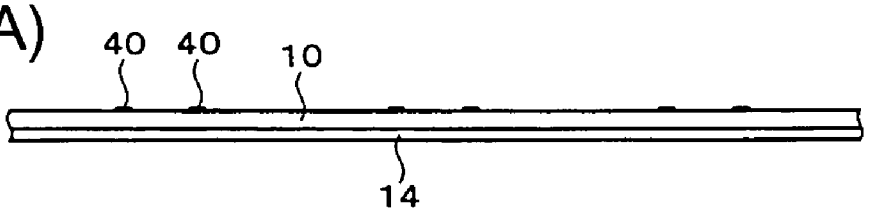


FIG.8 (B)

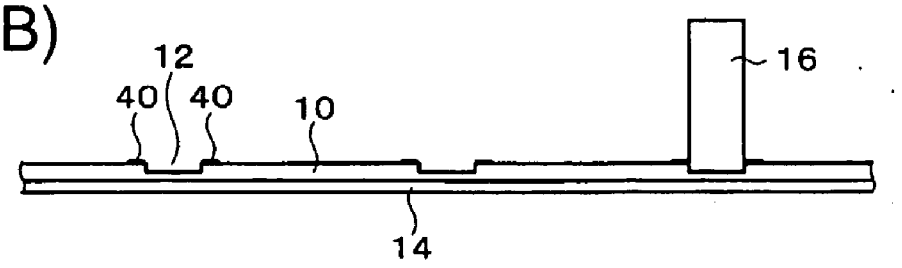


FIG.8 (C)

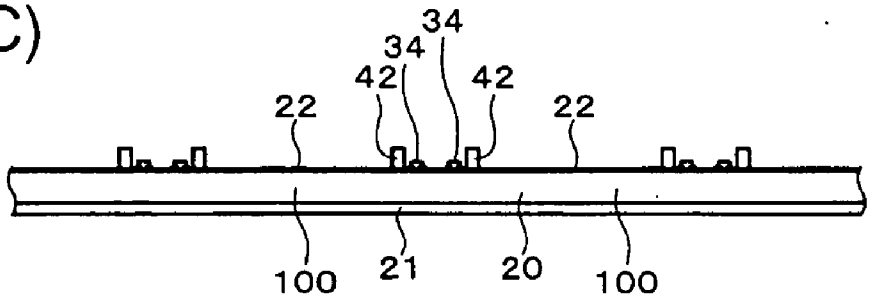


FIG.8 (D)

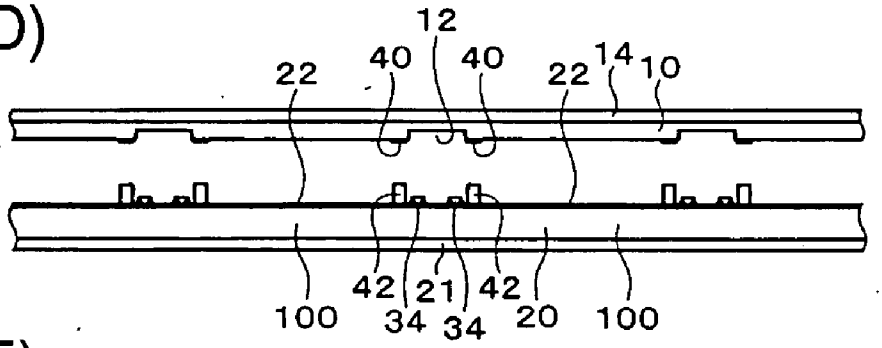


FIG.8 (E)

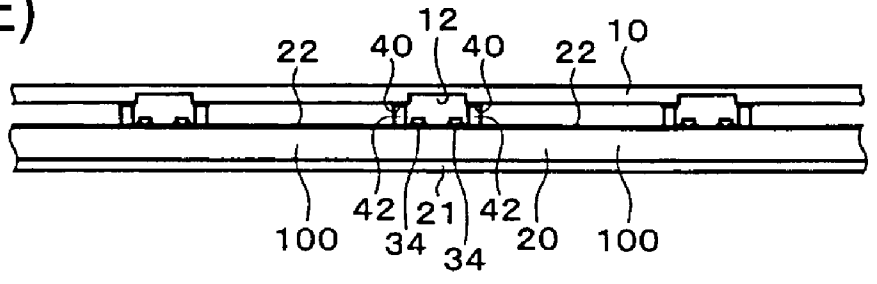


FIG.9 (A)

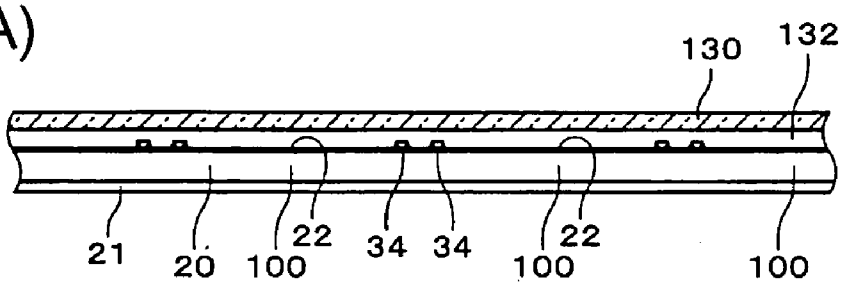


FIG.9 (B)

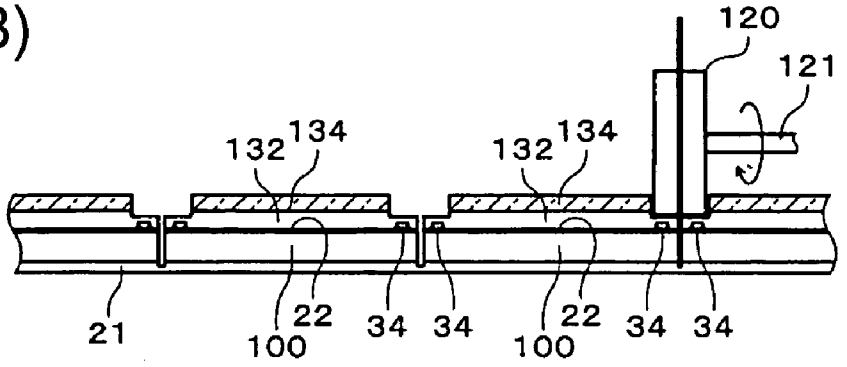


FIG.9 (C)

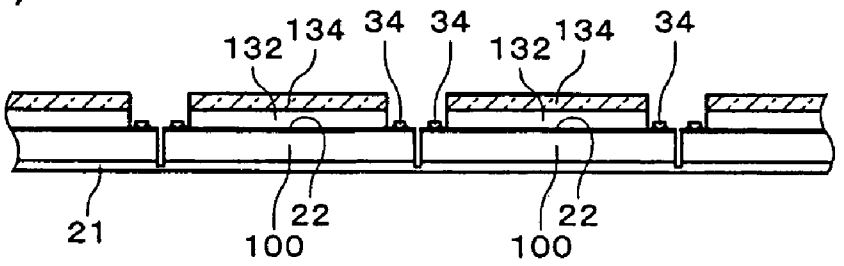


FIG.10 (A)

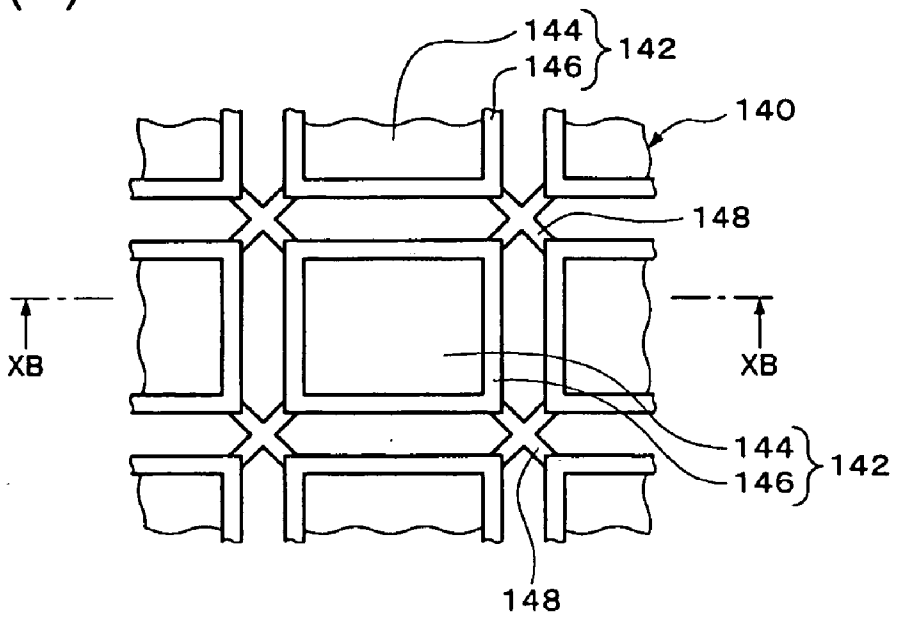


FIG.10 (B)

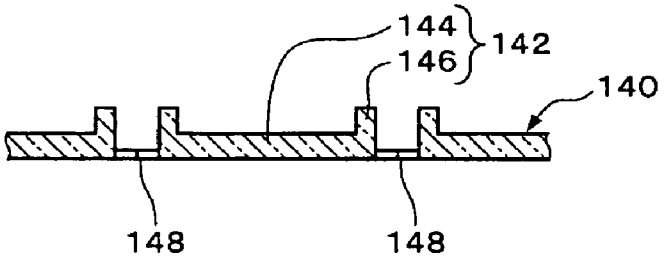


FIG.11

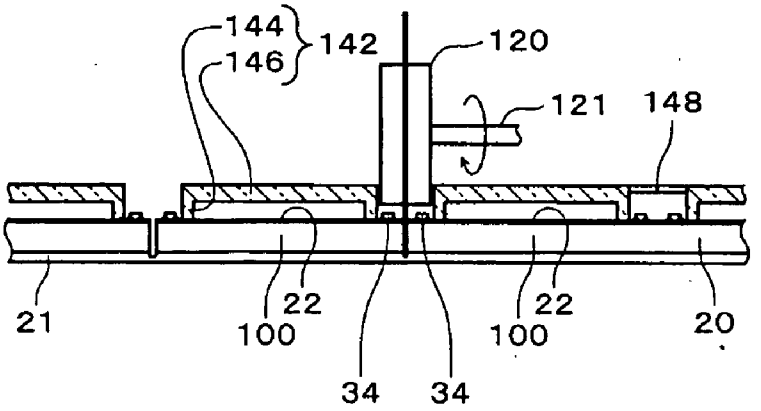


FIG.12

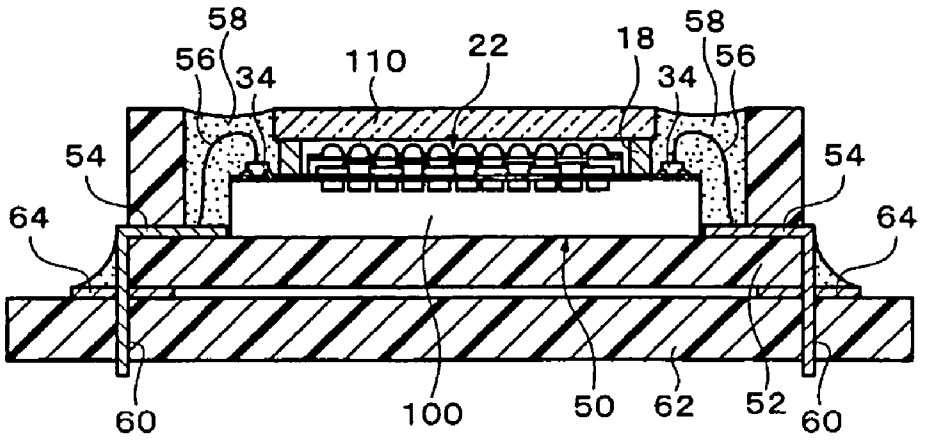


FIG.13

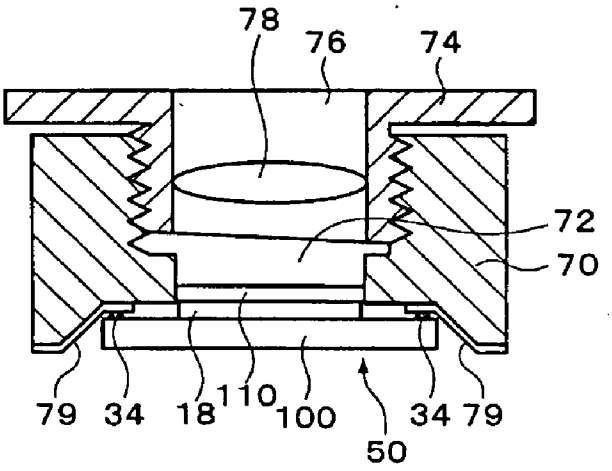


FIG.14

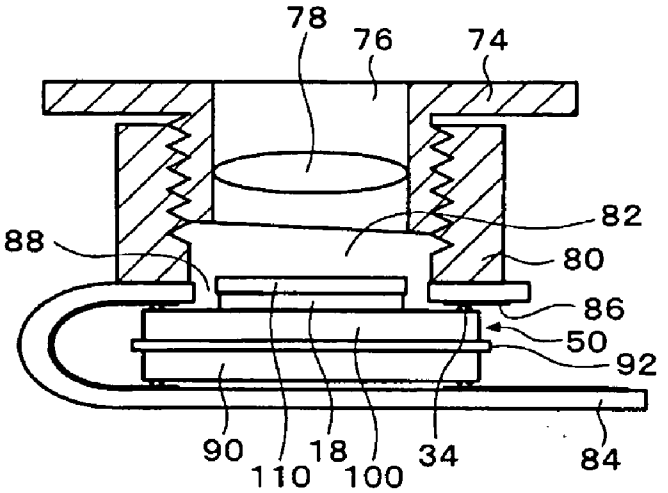


FIG.15

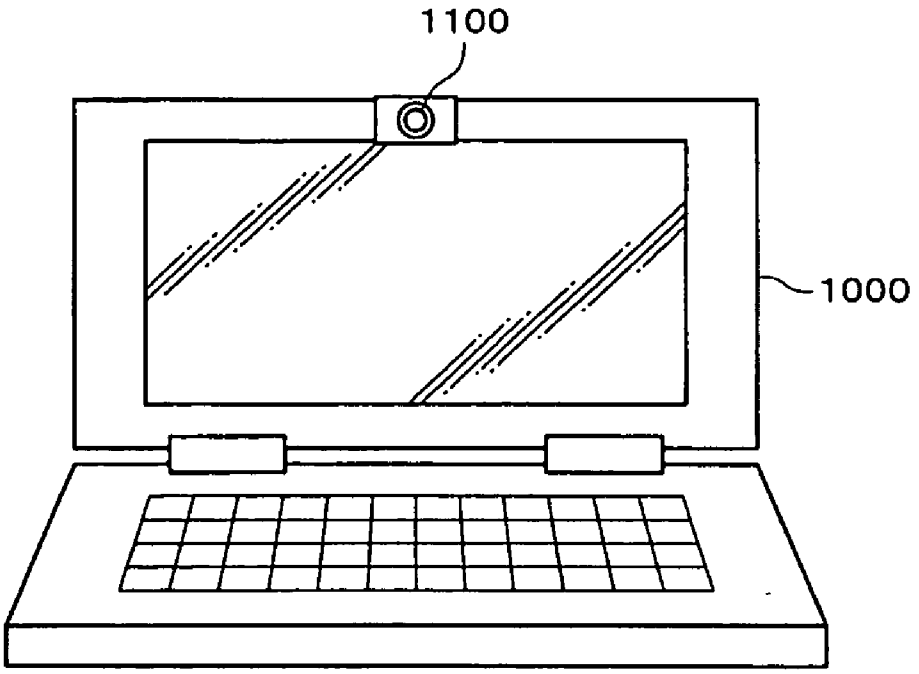


FIG.16

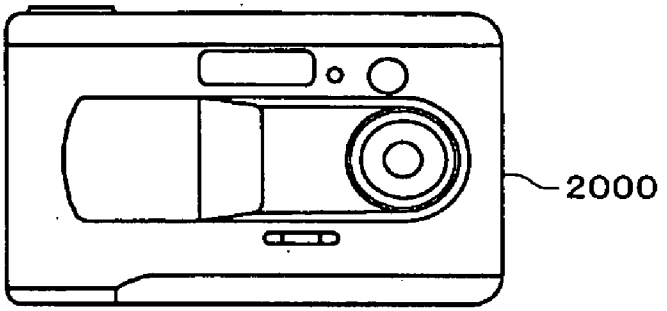


FIG.17 (A)

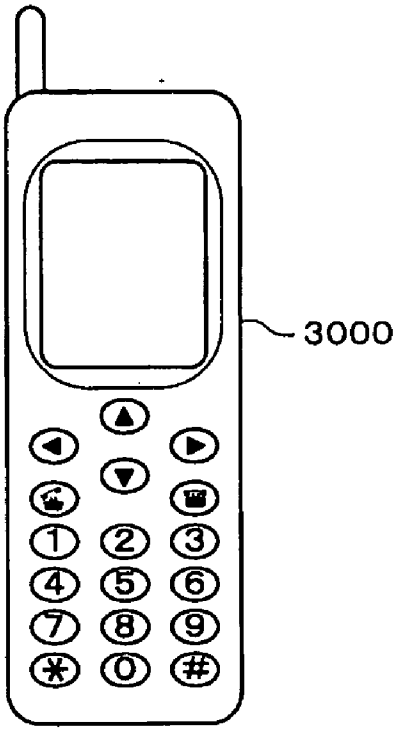
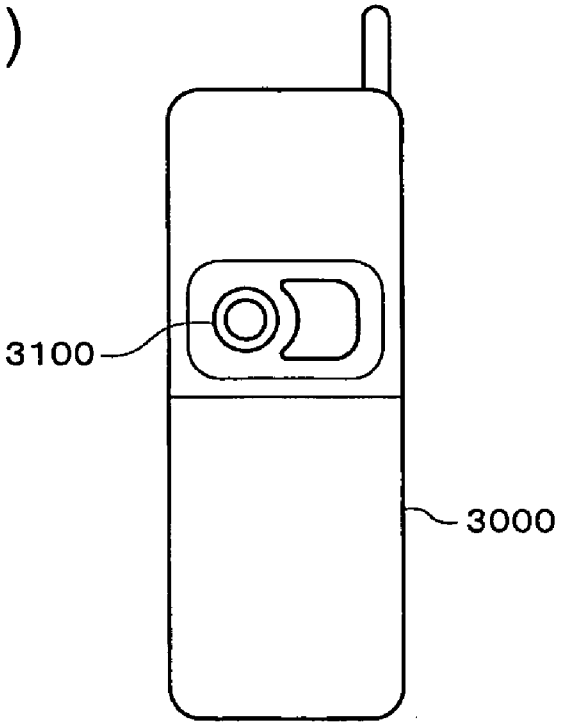


FIG.17 (B)



SEMICONDUCTOR DEVICE, METHOD OF MANUFACTURING THE SAME, CIRCUIT SUBSTRATE AND ELECTRONIC EQUIPMENT

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a semiconductor device, a method of manufacturing the same, a circuit substrate and electronic equipment.

[0003] 2. Description of Related Art

[0004] It is known that an optical chip including an optical unit such as a light receiving part preferably has a space between the optical unit and a cover for sealing the optical unit. Therefore, a method is known for manufacturing an optical device in which an optical chip is cut into individual pieces, thereafter the optical unit is sealed by the cover so that a space is formed between the optical unit and the cover. When a substrate such as a wafer is cut by dicing and the like, substrate shavings resulting from dicing or other wastes are generated. Furthermore, when the waste is attached to the optical unit and sealed together without being removed, there is a problem that the waste can not be removed from the space after the optical unit has been sealed, so that the quality of the optical device decreases. Specifically, in a case of a solid-state imaging device having an optical unit provided with a microlens, since a microlens has a concavo-convex shape, the above waste is easy to adhere thereto and is difficult to be completely removed. Thus, in a case of a solid-state imaging device having an optical unit provided with a microlens, there is a problem that the quality thereof easily decreases.

[0005] The present invention is intended to enhance the reliability and the productivity of a product.

SUMMARY OF THE INVENTION

[0006] A method of manufacturing a semiconductor device according to the present invention includes the steps of (a) connecting a first substrate with a second substrate disposed to be stacked on the first, and (b) cutting the first substrate and the second substrate in the same process with a cutting tool. Here, the cutting tool includes a plurality of cutters disposed close to each other, having different cut widths. In addition, the first substrate and the second substrate are cut with the cutting tool so as to have different cut widths of the first substrate and the second substrate in the step (b). According to the present invention, a plurality of the substrates which are stacked are cut in the same process so as to have different cut widths of the substrates. Therefore, there is no need for cutting the substrates in numbers, so that the productivity of the semiconductor device is enhanced.

[0007] In the method of manufacturing a semiconductor device, at least a part of the first substrate may have optical transparency. Furthermore, the second substrate may include a part which becomes an optical chip including an optical unit. Here, the part includes a plurality of parts.

[0008] In the method of manufacturing a semiconductor device, step (b) may also include the step of inserting the cutting tool into the first substrate and the second substrate from a side of the first substrate.

[0009] In the method of manufacturing a semiconductor device, the cutting tool may include a first cutter cutting the first substrate and a second cutter cutting the second substrate. In addition, a cut width of the first substrate by the first cutter may be larger than a cut width of the second substrate by the second cutter, in step (b).

[0010] In the method of manufacturing a semiconductor device, the length of the first cutter may be larger than the thickness of a part which is cut, of the first substrate.

[0011] In the method of manufacturing a semiconductor device, the length of the second cutter may be larger than the thickness of a part which is cut, of the second substrate.

[0012] In the method of manufacturing a semiconductor device, step (b) may also include the step of positioning the first cutter with an interval from a surface of the second substrate at the time of cutting the second substrate. This can avoid cutting the second substrate with the first cutter.

[0013] In the method of manufacturing a semiconductor device, an electrode may be formed on the part which becomes an optical chip on the second substrate, and outside the optical unit. In addition, a part of the first substrate located above the electrode may be removed with the first cutter in step (b). This enables a space above the electrode of the second substrate to be opened, so that a connection to the electrode is easily established.

[0014] The method of manufacturing a semiconductor device may also include the steps of attaching a sheet to the second substrate before step (b), and cutting the second substrate not so as to penetrate the sheet with the cutting tool in step (b). This enables the second substrate which was cut to be retained on the sheet, and thereby the following processes are facilitated.

[0015] The method of manufacturing a semiconductor device may also include the steps of forming a trench along a cut line of the first substrate before step (b), and cutting the first substrate along the cut line in step (b). This enables the cut line to be made thinner than other parts of the substrate, so that the first substrate can be easily cut with the first cutter. In addition, forming the trench clearly specifies a cut position of the first substrate.

[0016] In the method of manufacturing a semiconductor device, step (b) may also include the step of cutting and separating the first substrate and the second substrate into individual pieces that include a part of the first substrate and a part of the second substrate which are placed face to face and fixed to each other.

[0017] In the method of manufacturing a semiconductor device, step (a) may also include the steps of placing the first substrate and the second face to face through a spacer, and fixing the first substrate to the second substrate through the spacer.

[0018] In the method of manufacturing a semiconductor device, step (a) may also include the steps of bonding the first substrate with the second substrate through an optically transparent adhesive, and fixing the first substrate to the second substrate through the optically transparent adhesive.

[0019] The method of manufacturing a semiconductor device may also include the steps of forming a connecting part which connects a plurality of covers to each other in the

first substrate, fixing a plurality of the covers to the second substrate in step (a), and cutting the connecting part in the (b).

[0020] A semiconductor device according to the present invention is manufactured by the method described above. Also, a semiconductor device according to the present invention includes the semiconductor device described above and a supporting member which supports the semiconductor device. Further, onto a circuit substrate according to the present invention, the semiconductor device described above is mounted. Moreover, electronic equipment according to the present invention includes the semiconductor device described above.

BRIEF DESCRIPTION OF DRAWINGS

[0021] FIGS. **1**(A) through **1**(C) are diagrams illustrating a method of manufacturing a semiconductor device according to a first embodiment of the present invention.

[0022] **FIG. 2** is a diagram illustrating the method of manufacturing a semiconductor device according to the first embodiment of the present invention.

[0023] **FIG. 3** is a diagram illustrating the method of manufacturing a semiconductor device according to the first embodiment of the present invention.

[0024] FIGS. **4**(A) and **4**(B) are diagrams illustrating the method of manufacturing a semiconductor device according to the first embodiment of the present invention.

[0025] FIGS. **5**(A) and **5**(B) are diagrams illustrating the method of manufacturing a semiconductor device according to the first embodiment of the present invention.

[0026] FIGS. **6**(A) and **6**(B) are diagrams illustrating a semiconductor device according to the first embodiment of the present invention.

[0027] FIGS. **7**(A) and **7**(B) are diagrams illustrating a method of manufacturing a semiconductor device according to a modification of the first embodiment of the present invention.

[0028] FIGS. **8**(A) through **8**(E) are diagrams illustrating a method of manufacturing a semiconductor device according to another modification of the first embodiment of the present invention.

[0029] FIGS. **9**(A) through **9**(C) are diagrams illustrating a method of manufacturing a semiconductor device according to a second embodiment of the present invention.

[0030] FIGS. **10**(A) and **10**(B) are diagrams illustrating a method of manufacturing a semiconductor device according to a third embodiment of the present invention.

[0031] **FIG. 11** is a diagram illustrating the method of manufacturing a semiconductor device according to the third embodiment of the present invention.

[0032] **FIG. 12** is a diagram illustrating a semiconductor device and a circuit substrate according to an embodiment of the present invention.

[0033] **FIG. 13** is a diagram illustrating a semiconductor device according to an embodiment of the present invention.

[0034] **FIG. 14** is a diagram illustrating a semiconductor device according to an embodiment of the present invention.

[0035] **FIG. 15** is a diagram showing electronic equipment according to an embodiment of the present invention.

[0036] **FIG. 16** is a diagram showing electronic equipment according to an embodiment of the present invention.

[0037] FIGS. **17**(A) and **17**(B) are diagrams showing electronic equipment according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0038] An embodiment of the present invention will be described hereinafter referring to the accompanying drawings.

[0039] (First Embodiment)

[0040] FIGS. **1**(A) through **6**(B) are diagrams illustrating a semiconductor device and a method of manufacturing the same according to a first embodiment of the present invention. In the present embodiment, an optical device and a method of manufacturing the same will be described as an example. In the present embodiment, a first substrate **10** and a second substrate **20** are used.

[0041] As shown in **FIG. 1**(A), the first substrate **10** is prepared. Although the size and the shape of the first substrate **10** are not specifically limited, the size is preferably the same as that of the second substrate **20**, and the shape is more preferably the same as that of the second substrate **20**. Furthermore, the substrate **10** may be, for example, a quadrangle as shown in **FIG. 3**. At least a part of the first substrate **10** has optical transparency. Optical glass can be used as the first substrate **10**. If only the first substrate **10** is optically transparent, the magnitude of the optical loss thereof is of no object. In addition, the first substrate **10** may transmit only light having a specific wavelength. For example, the first substrate **10** may not transmit light in the infrared range but transmit visible light. The optical loss of the first substrate **10** may be small for visible light and may be large for light in the infrared range. Furthermore, optically functional films such as an antireflective coat and an infrared blocking film may be formed on a surface of the first substrate **10**. This saves the need for installing a member having an optical function in addition to a substrate, so that an optical device and the like can be further reduced in size.

[0042] A trench **12** may be formed on the first substrate **10** as shown in **FIG. 1**(A). When the trench **12** is formed by cutting the first substrate **10**, attaching a supporting member such as a sheet **14** to the substrate **10** improves the efficiency of the job for the process so as to avoid cracks in the first substrate **10**. The trench **12** may be formed by half-cutting the first substrate **10**. The half-cutting technique is not cutting the first substrate **10** completely, but forming the trench **12** by cutting the first substrate **10** along a thickness direction thereof as shown in **FIG. 1**(A). In this case, the trench **12** may be formed by cutting from a surface of the first substrate **10** with a dicing blade **16**. The trench **12** is formed on a cut line (a virtual line for cutting) of the first substrate **10**. Namely, in a cutting process described later, the first substrate is cut along the cut line. For example, as shown in **FIG. 3**, the trench **12** here including a plurality of trenches may be laid out in a lattice structure. Forming the trench **12** makes the thickness of the first substrate **10** at the cut line be thinner than other parts of the first substrate **10**,

and thereby the first substrate **10** can be easily cut with a cutting tool **120** (specifically, a first cutter **122**) described later. In addition, forming the trench **12** enables a cut position of the first substrate **10** to be clearly specified. As a modification, the first substrate **10** may not include the trench **12**.

[**0043**] Next, in the present embodiment, the first and the second substrates **10** and **20** are attached to each other through at least a single spacer **18**. The spacer **18** which is provided may include a plurality of spacers. For example, the spacer **18** is formed on one of the first and the second substrates **10** and **20**. Then, one of the first and the second substrates **10** and **20** is attached to the other of the first and the second substrates **10** and **20** through spacer **18**. As an example, the spacer **18** of a lattice structure is provided on the first substrate **10** as shown in **FIG. 1**(B). The spacer **18** is provided on each part which is cut to become a transparent substrate **110**, of the first substrate **10**. In the example shown in **FIG. 1**(B), spacers **18** are each provided to surround the trench **12** (see, **FIG. 3**). The spacer **18** may be formed continuously (without a break) with an adjacent spacer. In this case, attaching of the spacer **18** is facilitated. The spacer **18** has a form surrounding an optical unit **22** described later.

[**0044**] In the present embodiment, the spacer **18** is formed by a resin. In view of adhesion to the first and the second substrates **10** and **20**, the resin having adhesiveness, such as thermoplastic resin, light curable resin, heat curable resin, a combination of these resin may be used. For example, the spacer **18** may be formed by forming a layer of photosensitive resin (a photo resist such as photosensitive polyimide) on the first substrate **10**, thereafter applying photolithography thereto for patterning the layer. Otherwise, the spacer **18** may be formed by screen printing. Here, temporarily curing the spacer **18** formed by a light curable resin or a heat curable resin can avoid transforming thereof. In addition, when the resin forming the spacer **18** is ultraviolet rays (UV) curable, weak irradiation of UV is available for temporarily curing. Here, temporarily cured means a condition where the resin has not been completely cured, and where the fluidity of the temporarily cured resin is lower than that of the resin under room temperature. This prevents the resin from transforming when the first and the second substrates **10** and **20** are attached to each other through the spacer **18**, and thereby the resin can be prevented from attaching to the optical unit **22** described later. Therefore, the disadvantage of inputting and outputting of light to and from the optical unit due to adhesion of the resin can be avoided. Furthermore, at least a surface of the spacer **18** is preferably composed of an insulating material.

[**0045**] As shown in **FIG. 1**(C), the second substrate **20** is prepared. A sheet **21** may be attached to the second substrate **20** in order to improve the efficiency of the processing job in the cutting process described later. **FIG. 2** is a diagram showing a magnification of a part of the second substrate **20**. The second substrate **20** has an optical chip **100** here including a plurality of optical chips which includes the optical unit **22**. The optical chip **100** includes the optical unit **22** and electrodes **34**. The optical unit **22** includes a part (a light receiving part or a light emitting part) which light enters or is emitted from, and a part for converting optical energy into other energy (for example, electrical energy) or for converting other energy (for example, electrical energy) into optical energy. One of the optical units **22** may include an energy converting part (a light receiving part or a light emitting part) **24** including a plurality of energy converting parts.

[**0046**] In the present embodiment, as an example, a solid-state imaging device (for example, a CCD, specifically a CCD provided with a photo diode, and an image sensor such as a CMOS sensor) will be described. In this case, each optical unit **22** includes the energy converting part (a light receiving part, an image sensing part, or the like) **24** including a plurality of energy converting parts. As shown in **FIG. 2**, the energy converting part **24** includes a plurality of energy converting parts two-dimensionally arranged so as to sensor an image. The energy converting part **24** may be covered by a passivation film **26** which has optical transparency. When the second substrate **20** includes a semiconductor substrate (for example, a semiconductor wafer), the passivation film **26** may be formed by a silicon oxide film or a silicon nitride film.

[**0047**] The optical unit **22** may include a color filter **28**. The color filter **28** may be formed on the passivation film **26**. In addition, a planerizing layer **30** may be installed on the color filter **28**. A microlens array **32** may be formed on a surface of the optical unit **22**. In this case, the first substrate **10** and the spacer **18** seal at least an area where the microlens array **32** is formed, among areas on the second substrate **20**.

[**0048**] A plurality of the electrodes **34** are formed on the second substrate **20**. Although the electrodes **34** shown in **FIG. 2** include a bump formed on a pad, it may include only the pad. As shown in **FIG. 2**, the electrodes **34** are preferably formed outside the optical unit **22**, on a part which becomes the optical chip **100**. For example, the electrodes **34** may be formed between two of adjacent optical units (which are referred to as the optical unit **22**). One group of the electrodes **34** (including a plurality of electrodes) correspond to a single optical unit **22**. For example, as shown in **FIG. 6**(B), the electrodes **34** may be disposed along a plurality of sides of the optical unit **22** (for example, on two opposed sides). Furthermore, the electrodes **34** may be disposed along a single side of the optical unit **22**.

[**0049**] A mark for recognizing a cut line (not shown in the drawing) is preferably formed on the second substrate **20**. When the first substrate **10** is optically transparent, the mark on the second substrate **20** may be recognized through the first substrate **10**.

[**0050**] As shown in **FIG. 1**(C), the first and the second substrates **10** and **20** are placed face to face. Specifically, a plane where the optical unit **22** is formed, of the second substrate **20** and the first substrate **10** are placed face to face. **FIG. 3** is a plan view showing the first and the second substrates **10** and **20** which are placed face to face. When the first substrate **10** includes the trench **12**, a plane having the trench **12** may be opposed to the second substrate **20**. In addition, when a supporting member such as the sheet **14** is provided on the first substrate **10**, an opposite side of the plane where the supporting member is provided may be opposed to the second substrate **20**. In this case, the spacer **18** intervenes between the first and the second substrates **10** and **20**. The spacer **18** is disposed to surround the optical unit **22** of the second substrate **20** (see, **FIG. 6**(B)).

[**0051**] As shown in **FIG. 4**(A), the first and the second substrates **10** and **20** are attached to each other through the

spacer **18**. For example, when the spacer **18** is formed by a heat curable resin, the spacer **18** provided on the first substrate **10** is in contact with the second substrate **20**, thereafter the spacer **18** is heated so as to develop adhesion thereof. In addition, for example, when the first substrate **10** is optically transparent, the spacer **18** may be formed by a light curable resin. Then, the spacer **18** may be bonded to the second substrate **20** by irradiating the spacer **18** with light from a side of the first substrate **10**. Otherwise, an adhesive may be provided between the second substrate **20** and the spacer **18**. In this case, when the first substrate **10** is optically transparent, and the adhesive is a light curable resin, the spacer **18** may be bonded to the second substrate **20** by irradiating the adhesive with light from a side of the first substrate **10**. Thus, the optical unit **22** is sealed by the first substrate **10** and the spacer **18**. In the present embodiment, the optical unit **22** is sealed so that a space is formed between the first and the second substrates **10** and **20**. Here, the space may be evacuated to the extent that the pressure thereof becomes lower than atmosphere pressure, or that the space becomes a vacuum. Otherwise, the space may be filled with nitrogen, dry air, and the like. For example, the above structure is obtained by performing a sealing process under the pressure lower than atmosphere pressure or a vacuum, or under an atmosphere of nitrogen, dry air, or the like. This enables water vapors and the like in the space to be reduced. Therefore, dew condensation in products such as a semiconductor device and an electrical part, and bursting of a product due to an increase of the pressure of the space in a heating process, can be avoided. Here, the sheet **14** attached to the first substrate **10** is peeled off, if necessary. Furthermore, the first and the second substrates **10** and **20** are preferably cleaned and dried right before the sealing process. The reason is that cleaning the optical unit **22** right before sealing enables dust and the like in the space to be avoided, so that a yield of a final product can be further improved.

[**0052**] Next, a cutting process of the first and the second substrates **10** and **20** will be described. Here, **FIG. 5**(A) and **FIG. 5**(B) are magnified diagrams of the first and the second substrates for explaining this process.

[**0053**] In this process, as shown in **FIG. 4**(B), the first and the second substrates **10** and **20** are cut in a lump (simultaneously). The cutting is performed avoiding a part which becomes the transparent substrate **110**, of the first substrate **10**. Namely, the first substrate **10** is cut outside an area surrounded by the spacer **18** (where the optical unit **22** is located) and the spacer **18**, or is cut so that at least a part of the spacer **18** remains. The first substrate **10** may be cut along the trench **12**.

[**0054**] This process is performed using the cutting tool **120**. The cutting tool **120** may be a blade used for dicing of a semiconductor wafer. For example, the cutting tool **120** is formed into a disk shape. A shaft part **121** connected to the center of the disk rotates, and thereby the first and the second substrates **10** and **20** are cut with a blade (for example, an abrasive grain) formed on a periphery part of the cutting tool **120**.

[**0055**] As shown in **FIG. 5**(A), the cutting tool **120** includes a plurality of cutters (in **FIG. 5**(A), a first cutter **122** and a second cutter **124**). Each cutter cuts any substrate of a plurality of the substrates which are stacked. Specifically, the first cutter **122** cuts the first substrate **10**, while the second cutter **124** cuts the second substrate **20**. A plurality of the cutters (the first and the second cutters **122** and **124**) are disposed on the same cut line, and thereby a plurality of the substrates (the first and the second substrates **10** and **20**) are cut in the same process (for example, in a lump) as the cutting tool **120** moves. Here, the first and the second cutters **122** and **124** are a part of the cutting tool **120**. The cutters may be integrally formed from one member, or may be formed by combining individual members.

[**0056**] In this process, any substrate of a plurality of the substrates is cut so that a cut width thereof is different from that of another substrate. Specifically, the first and the second substrates **10** and **20** are cut so as to have different cut widths. For example, the first and the second cutters **122** and **124** are formed into a disk shape and have a blade (for example, an abrasive grain) on a periphery part thereof, and then the width of each periphery part (the thickness of the blade) is different from each other. Namely, a plurality of step parts are formed by the first and the second cutters **122** and **124**, on the periphery part of the cutting tool **120**.

[**0057**] As shown by a chain double-dashed line of **FIG. 5**(A), a cut width of the first substrate **10** may be larger than that of the second substrate **20**. Namely, as shown in **FIG. 5**(A), the width W1 of the first cutter **122** (the thickness of the blade) may be larger than the width W2 of the second cutter **124** (the thickness of the blade).

[**0058**] In addition, the width W1 of the first cutter **122** is practically the same as the width of the trench **12**. Here, being practically the same includes cases where the widths are completely the same, and where the widths are the same in consideration of a margin of error. Otherwise, the width W1 of the first cutter **122** may be smaller than the width of the trench **12**. In this case, the first substrate **10** is cut inside the trench **12**, so that the transparent substrate **110** includes a step on an edge part. Otherwise, the width W1 of the first cutter **122** may be larger than the width of the trench **12**. Furthermore, the width W1 of the first cutter **122** may be larger than an interval between two adjacent spacers (which are referred to as the spacer **18**). In this case, a part of the spacer **18** is cut when the first substrate **10** is cut.

[**0059**] The second cutter **124** cuts the second substrate **20** outside the optical unit **22**, and further outside the electrodes **34**. Between two of the adjacent optical units (which are referred to as the optical unit **22**), the electrodes **34** which correspond to the optical unit **22** are formed. The second substrate **20** is cut between two of the electrodes **34** (including a plurality of electrodes). Here, as shown in **FIG. 5**(A), the periphery part of the first and the second cutters **122** and **124** may be in a sharp shape.

[**0060**] The length L1 of the first cutter **122** (the length of a part which is outside the shaft part **121** of the cutting tool **120**, of the first cutter **122**) is larger than at least the thickness of the first substrate **10** at the cut line (for example, the thickness of a trench part). In addition, the length L2 of the second cutter **124** (the length of a part which is outside the first cutter **122**, of the second cutter **124**) is larger than at least the thickness of the second substrate **20**.

[**0061**] As shown in **FIG. 5**(B), the first and the second cutters **122** and **124** may be inserted into the first and the second substrates **10** and **20** from a side of the first substrate **10**. The cutting tool **120** moves along and parallel to the cut

line (for example, the trench **12**) as shown in **FIG. 5**(B). The edge part (the periphery part) of the first cutter **122** is positioned above the second substrate **20** with an interval. In the example shown in **FIG. 5**(B), since a plane where the trench **12** is formed, of the first substrate **10** faces the second substrate **20**, a surface of the first substrate **10** keeps away from the second substrate **20**, so that the first cutter **122** hardly contacts the second substrate **20**. This can prevent the first cutter **122** from cutting the second substrate **20**.

[**0062**] In the example shown in **FIG. 5**(B), the first and the second substrates **10** and **20** are cut (full-cut) into an individual piece in order to obtain the optical chip **100** including a single optical unit **22** which is sealed. As a modification, for example, the second substrate **20** may not be completely cut into an individual piece but may be cut (for example, half-cut) to the extent that a trench is formed on a surface thereof. In this case, in the following process, the second substrate **20** may be isolated into an individual piece along the trench formed on the surface by polishing the second substrate **20** from a back side so as to obtain the optical chip **100**.

[**0063**] A part which is above the electrodes **34**, of the first substrate **10** may be removed with the first cutter **122**. This can open a space above the electrodes **34** disposed between two adjacent transparent substrates (which are referred to as the transparent substrate **110**), when the first substrate **10** is cut into the transparent substrate **110** here including a plurality of transparent substrates which is an individual piece. Therefore, since a space above the electrodes **34** of the second substrate **20** is opened, an electrical connection to the electrodes **34** is easily established.

[**0064**] When the sheet **21** is attached to the second substrate **20**, the second substrate **20** is preferably cut (full-cut, in **FIG. 5**(B)) so that the sheet **21** is not penetrated. This enables the second substrate **20** which was cut to be retained on the sheet **21**, so that the following processes are facilitated. Specifically, in a case of the first and the second substrates **10** and **20** being cut into individual pieces, a plurality of the individual pieces can be held in a lump, so that following processes are greatly facilitated.

[**0065**] According to the method of manufacturing a semiconductor device according to the present embodiment, the first and the second substrates **10** and **20** which are stacked are cut in a lump so as to have different cut widths. Therefore, there is no need for cutting the substrates in numbers, so that the productivity of the semiconductor device can be enhanced. Furthermore, since the first and the second substrates **10** and **20** are cut after the optical unit **22** is sealed, dust is not mixed in the sealed part, so that the reliability of a semiconductor device can be enhanced.

[**0066**] **FIG. 6**(A) and **FIG. 6**(B) are diagrams explaining the semiconductor device according to the present embodiment. In the present embodiment, an optical device will be described as an example. The optical device includes the transparent substrate **110**, the optical chip **100**, and the spacer **18**. Light enters the optical unit **22** from the transparent substrate **110**. The optical unit **22** formed on the optical chip **100** is sealed by the transparent substrate **110** and the spacer **18**. A space is formed between the optical unit **22** and the transparent substrate **110**. The space may be a vacuum, or may be filled with nitrogen and dry air. This avoids dew condensation in the optical unit **22**. The electrodes **34** are provided on the optical chip **100**, outside the optical unit **22**, and further outside a member sealing the optical unit **22** (the transparent substrate **110** and the spacer **18**). Other details are the same as the details explained in the previous embodiment of the method of manufacturing a semiconductor device.

[**0067**] **FIG. 7**(A) through **FIG. 8**(E) are diagrams showing a modification of the present embodiment. In the following explanation, contents (a structure, an action, a function, and an effect) which are the same as those of other embodiments and are assumable will be omitted. Here, the present invention includes contents achieved by combining a plurality of embodiments.

[**0068**] **FIG. 7**(A) and **FIG. 7**(B) are diagrams illustrating a method of manufacturing a semiconductor device according to a modification of the present embodiment. In this modification, as shown in **FIG. 7**(A), the spacer **18** is formed on the second substrate **20**. When a passivation film is formed on the second substrate **20**, the spacer **18** may be formed thereon. Otherwise, the passivation film may not be formed on an area where the spacer **18** is formed. Then, as shown in **FIG. 7**(B), the first substrate **10** is attached to the spacer **18**. The details described about connecting the second substrate **20** to the spacer **18** can be applied to connecting the first substrate **10** to the spacer **18**.

[**0069**] **FIG. 8**(A) through **FIG. 8**(E) are diagrams illustrating a method of manufacturing a semiconductor device according to another modification of the present embodiment. Although the first and the second substrates **10** and **20** are also used in this modification, the spacer is formed by a metal. Namely, the spacer is formed by a metal on one of the first and the second substrates **10** and **20**, and then the other of the first and the second substrates **10** and **20** is attached to the spacer.

[**0070**] As shown in **FIG. 8**(A), a brazing material (or a seal metal) **40** is provided on the first substrate **10**. The brazing material **40** may be either of a soft-soldering material and a hard-soldering material. A method of providing the brazing material **40** may be any of vapor deposition, sputtering, CVD, and plating (for example, electroless plating). If the brazing material **40** is a paste material as a soldering paste, screen printing may be applied. The brazing material **40** is provided on a position where the spacer is attached.

[**0071**] As shown in **FIG. 8**(B), the trench **12** is formed on the first substrate **10**. Although the trench **12** is formed after the brazing material **40** is provided in this modification, the order may be reversed.

[**0072**] As shown in **FIG. 8**(C), a spacer **42** is formed on the second substrate **20**. The spacer **42** is formed by metals such as nickel and gold. Plating (for example, electroless plating) can be applied as a forming method of the spacer **42**.

[**0073**] As shown in **FIG. 8**(D), the first and the second substrates **10** and **20** are attached to each other through the spacer **42**. Specifically, the first substrate **10** is bonded to the spacer **42**. Brazing is applied to the bonding. Specifically, the brazing material **40** formed on the first substrate **10** is melted by heating so as to bond the first substrate **10** to the spacer **42**.

[**0074**] After the first and the second substrates **10** and **20** are attached to each other as shown in **FIG. 8**(E), the process

shown in **FIG. 4**(C) is performed. In the optical device according to the above methods, the optical unit **22** is sealed by the transparent substrate **110**, the spacer **42**, and the brazing material **40**. Here, a metal spacer may be provided on the first substrate **10**, and then the spacer may be bonded to the second substrate **20**. In addition, an adhesive may be used instead of the brazing material.

[**0075**] (Second Embodiment)

[**0076**] **FIG. 9**(A) through **FIG. 9**(C) are diagrams illustrating a method of manufacturing a semiconductor device according to a second embodiment of the present invention. In the present embodiment, a method of manufacturing an optical device will be described as an example, too. In the present embodiment, a first substrate **130** and the second substrate **20** are attached to each other through an adhesive layer **132**. The details of the first substrate **10** which have been explained in the previous embodiment can be applied to the first substrate **130**.

[**0077**] As shown in **FIG. 9**(A), the first and the second substrates **10** and **20** are attached to each other through the adhesive layer **132**. The adhesive layer **132** has optical transparency. Specifically, the optical transparency of the adhesive layer **132** may be as high as that of air. A thermoplastic resin may be used as the adhesive layer **132**. For example, a photosensitive resin (a photo resist and the like) which is thermoplastic may be used. Here, the adhesive layer **132** may be temporarily cured for easy handling. Then, adhesion thereof may be developed after the adhesive layer **132** contacts either the first and the second substrates **130** and **20**. For example, when the adhesive layer **132** is a UV curable thermoplastic resin, irradiating of UV can be applied to temporarily curing. In a case of the adhesive layer **132** being formed on a microlens array **32**, each absolute refractive index of both is different from each other. Specifically, when the microlens array **32** includes a convex lens, the absolute refractive index of the adhesive layer **132** is preferably smaller than that of the microlens array **32**. On the contrary, when the microlens array **32** includes a concave lens, the absolute refractive index of the adhesive layer **132** is preferably larger than that of the microlens array **32**.

[**0078**] The adhesive layer **132** may be continuously formed on the second substrate **20** to cover a part which becomes the optical chip **100** here including a plurality of parts. Namely, the adhesive layer **132** may be formed to cover the optical unit **22** here including a plurality of optical units and an area between two adjacent optical units (which are referred to as the optical unit **22**). The optical unit **22** is sealed by the adhesive layer **132**. As a modification, the adhesive layer **132** may be formed on the optical unit **22**, while avoiding the area between two adjacent optical units (which are referred to as the optical unit **22**).

[**0079**] As shown in **FIG. 9**(B), the first and the second substrates **130** and **20** are cut in a lump (simultaneously). Although a trench is not formed on the first substrate **130** in the present embodiment, a trench may be formed as the first embodiment. The first and the second substrates **130** and **20** are cut using the cutting tool **120**. In the example shown in **FIG. 9**(B), the first substrate **130** is cut so as to form the transparent substrate **134** here including a plurality of transparent substrates. The second substrate **20** is cut so as to form the optical chip **100** here including a plurality of optical chips. The optical unit **22** of the optical chip **100** is sealed by the transparent substrate **134** and the adhesive layer **132**. Here, the details of the cutting process are the same as the details explained in the first embodiment.

[**0080**] As shown in **FIG. 9**(C), when a part of the adhesive layer **132** remains between two of the adjacent transparent substrates (which are referred to as the transparent substrates **134**) (for example, on the electrodes **34**), a removing process thereof is performed. For example, etching with a solvent and sputtering, or ashing with plasma (**02** plasma and the like) can remove a part of the adhesive layer **132**, utilizing the transparent substrate **134** as a mask.

[**0081**] The present embodiment can also achieve the effects which have been previously explained in other embodiments. Other details are the same as the details explained in the first embodiment.

[**0082**] (Third Embodiment)

[**0083**] **FIG. 10**(A) through **FIG. 11** are diagrams illustrating a method of manufacturing a semiconductor device according to a third embodiment of the present invention. In the present embodiment, as an example, a method of manufacturing an optical device will be described, too. **FIG. 10**(B) is a sectional view along the XB-XB line in **FIG. 10**(A). In the present embodiment, a first substrate **140** is an aggregation of a plurality of covers **142**.

[**0084**] The covers **142** include a plate part **144** and a spacer part **146**. Although the form of the plate part **144** is not specifically limited, it is, for example, a quadrangle as shown in **FIG. 10**(A). The plate part **144** is disposed above the optical unit **22**. The spacer part **146** is formed into a convex shape on a periphery part of the plate part **144**. The spacer part **146** is continuously formed without a break. The spacer part **146** is disposed on a position surrounding the optical unit **22** and supports the plate part **144** above the optical unit **22**. The height of the spacer part **146** may be to the extent that a space is formed between the optical unit **22** and the plate part **144**. The covers **142** shown in **FIG. 10**(B) are a member into which the plate part **144** and the spacer part **146** are integrally formed. For example, the cover **142** can be formed by injection molding of resin. Two of the covers **142** adjacent to each other are coupled through a connecting part **148** so that each position is fixed. A plurality of the covers **142** and the connecting part **148** here including a plurality of connecting parts may be integrally formed (by, for example, injection molding).

[**0085**] As shown in **FIG. 10**(A), a plurality of the covers **142** which are rectangular may be arranged in a matrix. Then, corner parts of two of the covers **142** adjacent to each other may be coupled through the connecting part **148**. A plurality of the covers **142** (four, in the example shown in **FIG. 10**(A)) are connected to each other through a single connecting part **148**. The connecting part **148** may be formed thinner than the plate part **144**. As shown in **FIG. 10** (B), a plane of the connecting part **148** may be flush (or almost flush) with a plane which is on opposite sides to a projecting direction of the spacer part **146**, of the plate part **144**.

[**0086**] As shown in **FIG. 11**, the method of manufacturing a semiconductor device according to the present embodiment includes that the connecting part **148** is cut. Namely, a plurality of the covers **142** are attached to the second substrate **20** so as to seal any of the optical units **22** by the

covers **142**, thereafter the first and the second substrates **140** and **20** are cut in a lump (simultaneously). This cutting is performed using the cutting tool **120**. In the example shown in **FIG. 11**, the substrates are cut so that the connecting part **148** of the first substrate **140** is removed so as to isolate each of the covers **142** into individual pieces. Here, details of the cutting process are the same as the details explained in the first embodiment.

[**0087**] The present embodiment can also achieve the effects which have been previously explained in other embodiments. Other details are the same as the details explained in the first embodiment.

[**0088**] (Other Embodiments)

[**0089**] **FIG. 12** is a diagram illustrating a semiconductor device (for example, an optical module) and a circuit substrate according to an embodiment of the present invention. This optical module includes an optical device **50** equivalent to the optical device shown in **FIG. 6**(A). The optical device **50** is attached to a supporting member (for example, a case) **52**. A wiring **54** is formed on the supporting member **52**. The supporting member **52** may be a member which does not include the wiring **54** and the like. The supporting member **52** may be a molded interconnect device (MID). The wiring **54** is electrically connected to the electrodes **34** of the optical device **50**. For example, a wire **56** may be used for electrically connecting. In addition, a sealing material **58** is provided on the electrically connecting point (for example, the wire **56** and a part where the wire **56** is bonded). Namely, the electrically connecting point is sealed by the sealing material **58**. The sealing material **58** may be provided by, for example, potting. In the optical device **50**, since the optical unit **22** is sealed by the transparent substrate **110** and the spacer **18**, the optical unit **22** is not covered by the sealing material **58**. This is because the transparent substrate **110** and the spacer **18** act as a dam to block the sealing material **58**.

[**0090**] Apart of the wiring **54** is an external terminal (for example, a lead) **60**. The external terminal **60** is electrically connected to a wiring pattern **64** formed on a circuit substrate **62**. In the example shown in **FIG. 12, a** portion defining a hole is formed in the circuit substrate **62**, and then the external terminal **60** is inserted into the hole. A land of the wiring pattern **64** is formed around the hole. The external terminal **60** is bonded to the land with a brazing material (for example, solder). As described, the circuit substrate **62** is formed by mounting the optical module.

[**0091**] **FIG. 13** is a diagram illustrating a semiconductor device (for example, an optical module) according to an embodiment of the present invention. This optical module includes the optical device **50** equivalent to the optical device shown in **FIG. 6**(A) and a supporting member **70** to which the optical device **50** is attached. A portion defining a hole **72** is formed in the supporting member **70**. At least a part of the transparent substrate **110** is located inside the hole **72**. In addition, a lens holder **74** is provided in the hole **72**. A portion defining a hole **76** is formed in the lens holder **74**. A lens **78** is provided inside the hole **76**. The holes **72** and **76** communicate with each other, so that light condensed by the lens **78** enters the optical device **50**. Here, the transparent substrate **110** may be a member which cuts light in the infrared range. Any adhesive, anisotropic conductive material, anisotropic conductive film, and metal bonding may be applied to connecting the electrodes **34** of the optical device **50** to the wiring **79** of the supporting member **70**. Furthermore, an underfill material not shown in the drawing may be provided between the optical device **50** and the supporting member **70**.

[**0092**] **FIG. 14** is a diagram illustrating a semiconductor device (for example, an optical module) according to an embodiment of the present invention. This optical module includes the optical device **50** equivalent to the optical device shown in **FIG. 6**(A) and a supporting member **80** to which the optical device **50** is attached. A portion defining a hole **82** is formed in the supporting member **80**. At least a part of the transparent substrate **110** is located inside the hole **82**. In addition, the lens holder **74** is provided in the hole **82** (as described in detail above).

[**0093**] In **FIG. 14**, the optical device **50** is mounted onto a substrate **84**. The electrodes **34** are bonded to a wiring pattern **86** formed on the substrate **84**. Any adhesive, anisotropic conductive material, anisotropic conductive film, and metal bonding may be applied to the bonding. Furthermore, an underfill material not shown in the drawing may be provided between the optical device **50** and the substrate **84**. A portion defining a hole **88** is formed in the substrate **84**. The holes **76**, **82** and **88** communicate with each other, so that light condensed by the lens **78** enters the optical device **50**.

[**0094**] An electronic unit (for example, a semiconductor chip) **90** is mounted (by, for example, face-down bonding) onto the substrate **84**. The electronic unit **90** and the wiring pattern **86** are electrically connected to each other. Besides, a plurality of electronic units not shown in the drawing may be mounted. The substrate **84** is bent so as to bond the electronic unit **90** to the optical device **50** through an adhesive **92**. Alternatively, the optical device **50** and the electronic unit **90** may be mounted onto the substrate **84** beforehand, and then the optical device **50** may be bonded to the electronic unit **90** by bending the substrate **84**.

[**0095**] As electronic equipment according to an embodiment of the present invention, a notebook personal computer **1000** shown in **FIG. 15** includes a camera **1100** provided with the optical module. In addition, a digital camera **2000** shown in **FIG. 16** includes the optical module. Furthermore, a cellular phone **3000** shown in **FIG. 17**(A) and **FIG. 17**(B) includes a camera **3100** provided with the optical module.

[**0096**] The present invention is not limited to the above embodiments but applied to various kinds of modifications. For example, the present invention includes a structure which is practically the same as that explained in the embodiments (for example, a structure whose function, method, and result are the same, or a structure whose aim and result are the same). In addition, the present invention includes a structure which is formed by replacing a nonessential parts of the structure explained in the embodiments. Furthermore, the present invention includes a structure having the same operation and result as those of the structure explained in the embodiments, or a structure which can achieve the same purpose as that thereof. In addition, the present invention includes a structure which is formed by adding a known technology to the structure explained in the description of the embodiments.

What is claimed is:

1. A method of manufacturing a semiconductor device, comprising of:

(a) connecting a first substrate with a second substrate disposed to be stacked on the first substrate; and

(b) cutting the first substrate and the second substrate in the same process with a cutting tool, wherein:

the cutting tool includes a plurality of cutters disposed close to each other, having different cut widths; and

the first substrate and the second substrate are cut with the cutting tool so that the first substrate and the second substrate have different cut widths, in step (b).

2. The method of manufacturing a semiconductor device according to claim 1, further comprising:

providing at least a part of the first substrate with optical transparency; and

forming the second substrate to include a part which becomes an optical chip including an optical unit with the part including at least a plurality of parts.

3. The method of manufacturing a semiconductor device according to claim 1 further comprising inserting the cutting tool into the first substrate and the second substrate from a side of the first substrate.

4. The method of manufacturing a semiconductor device according to claim 3, further comprising:

cutting the first substrate with a first cutter and cutting the second substrate with a second cutter; and

cutting a cut width of the first substrate by the first cutter larger than cutting a cut width of the second substrate by the second cutter, in step (b).

5. The method of manufacturing a semiconductor device according to claim 4, further comprising providing the length of the first cutter larger than the thickness of a part which is cut, of the first substrate.

6. The method of manufacturing a semiconductor device according to claim 4, further comprising providing the length of the second cutter is larger than the thickness of a part which is cut, of the second substrate.

7. The method of manufacturing a semiconductor device according to claim 4 further comprising positioning the first cutter with an interval from a surface of the second substrate at the time of cutting the second substrate.

8. The method of manufacturing a semiconductor device according to claim 4, further comprising:

forming an electrode on the part which becomes an optical chip on the second substrate, and outside the optical unit; and

removing a part of the first substrate located above the electrode with the first cutter in step (b).

9. The method of manufacturing a semiconductor device according to claim 8, further comprising:

attaching a sheet to the second substrate before step (b); and

cutting the second substrate not so as to penetrate the sheet with the cutting tool in step (b).

10. The method of manufacturing a semiconductor device according to claim 1, further comprising:

forming a trench along a cut line of the first substrate before step (b); and

cutting the first substrate along the cut line in step (b).

11. The method of manufacturing a semiconductor device according to claim 1, further comprising cutting and separating the first substrate and the second substrate into individual pieces that include a part of the first substrate and a part of the second substrate which are placed face to face and fixed to each other.

12. The method of manufacturing a semiconductor device according to claim 1, further comprising:

placing the first substrate and the second substrate face to face through a spacer; and

fixing the first substrate to the second substrate through the spacer.

13. The method of manufacturing a semiconductor device according to claim 1, further comprising:

bonding the first substrate with the second substrate through an optically transparent adhesive; and

fixing the first substrate to the second substrate through the optically transparent adhesive.

14. The method of manufacturing a semiconductor device according to claim 1, further comprising:

forming a connecting part which connects a plurality of covers to each other in the first substrate;

fixing a plurality of the covers to the second substrate in step (a); and

cutting the connecting part in step (b).

15. A semiconductor device manufactured by the method of manufacturing a semiconductor device according to claim 1.

16. A semiconductor device comprising the semiconductor device according to claim 15 and a supporting member which supports the semiconductor device.

17. A circuit substrate comprising the semiconductor device according to claim 15.

18. Electronic equipment comprising the semiconductor device according to claim 15.

19. A semiconductor device, comprising:

a first substrate with a second substrate disposed to be stacked on the first substrate; and

a cutting tool cutting the first substrate and the second substrate in the same process, wherein:

the cutting tool includes a plurality of cutters disposed close to each other, having different cut widths, and

the first substrate and the second substrate are cut with the cutting tool so that the first substrate and the second substrate have different cut widths.

20. A semiconductor device, comprising:

a first substrate connected with a second substrate disposed to be stacked on the first substrate; and

means for cutting the first substrate and the second substrate in the same process, wherein:

the means for cutting includes a plurality of cutters disposed close to each other, having different cut widths, and

the first substrate and the second substrate are cut with the means for cutting so that the first substrate and the second substrate have different cut widths.

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